CLAIMS

1. A transmitter for simultaneously transmitting n different signals in l directive beams, said transmitter comprising:

n beamformers receiving n different signals with each beamformer receiving a signal to be transmitted, each of said beamformers having m outputs for each signal to be transmitted, and wherein said n beamformers have an m x n output array;

m passive couplers each operatively connected to said n beamformers, wherein each passive coupler has n inputs for receiving said n different signals to be transmitted simultaneously from said n beamformers, each passive coupler having p outputs in phased relationship to one another; and

an antenna with an aperture within which a two-dimensional m x p array of radiating elements are disposed, said radiating elements connected to the outputs of the passive couplers and transmitting said n different signals simultaneously in l directive beams,

wherein each of said n beamformers receives steering control signals for determining the direction of transmission for each of said directive beams.

2. The transmitter of claim 1, further comprising mn single-signal transmit power amplifiers connected to the mn beamformer outputs and supplying an amplified signal to the mn passive coupler inputs.

3. The transmitter of claim 1, wherein the n different signals input to successive inputs of each passive coupler are split across the passive couplers p outputs with a phase incremented successively through multipliers of an incremental phase.

4. The transmitter of claim 1, wherein said m passive couplers comprise m Butler matrices.

5. The transmitter of claim 1, where n and p are equal.

6. The transmitter of claim 1, wherein n and l are equal.

7. The transmitter of claim 2, wherein said mn single-signal transmit power amplifiers are operated at saturation.

8. The transmitter of claim 7, wherein said mn single-signal transmit power amplifiers are class-C power amplifiers.

9. The transmitter of claim 1, wherein said n different signals to be transmitted comprise TDMA signals having a number of timeslots within a TDMA frame period.

10. The transmitter of claim 9, wherein said steering control signals are varied for each timeslot.

11. The transmitter of claim 10, further comprising a scheduler receiving the TDMA signals and varying said steering control signals to avoid creating adjacent beams in each timeslot.

12. The transmitter of claim 1, wherein each passive coupler input corresponds to transmission by the associated row of *p* radiating elements connected to the *p* outputs of the passive coupler with a fan-shaped radiation beam, with different passive coupler inputs producing fan beams at different angles relative to said phased array transmitter.

13. The transmitter of claim 1, further comprising *n* power amplifiers receiving the *n* different signals input to the *n* beamformers.

14. A transmitter for simultaneously transmitting $2n$ different signals in $2l$ directive beams, said transmitter comprising:

n beamformers receiving $2n$ different signals with each beamformer receiving two signals with first and second polarizations, respectively, each of said beamformers having m output pairs, for the first and second polarizations, where said n beamformers have a $2m \times n$ output array;

m passive coupler pairs each operatively connected to said n beamformers, wherein each passive coupler pair comprises a first passive coupler having n inputs for receiving n different signals of the first polarization, and a second passive coupler having n inputs for receiving n different signals of the second polarization, permitting all of said $2n$ different signals to be transmitted simultaneously, each of the first and second passive couplers having p outputs in phased relationship to one another defining $2p$ outputs for each passive coupler pair; and

an antenna with an aperture within which a two-dimensional $m \times p$ array of dual-polarization radiating elements are connected to the outputs of the passive coupler pairs, with each element having a connection for the first polarization and a connection for the second polarization,

wherein each of said n beamformers receives first and second steering control signals, for the first and second polarizations, respectively, for determining a direction of transmission for said directive beams.

15. The transmitter of claim 14, further comprising $2mn$ single-signal transmit power amplifiers connected to the $2mn$ beamformer outputs and supplying an amplified signal to the $2mn$ passive coupler inputs.

16. The transmitter of claim 14, wherein the first and second passive couplers of the *m* passive coupler pairs comprise Butler matrices.

17. The transmitter of claim 14, wherein *n* and *p* are equal.

18. The transmitter of claim 14, wherein *m* and *l* are equal.

19. The transmitter of claim 15, wherein said $2mn$ single-signal transmit power amplifiers are operated at saturation.

20. The transmitter of claim 19, wherein said $2mn$ single-signal transmit power amplifiers are class-C power amplifiers.

21. The transmitter of claim 14, wherein the $2n$ different signals to be transmitted comprise TDMA signals having a number of timeslots within a TDMA frame period.

22. The transmitter of claim 21, wherein said first and second steering control signals vary for each timeslot.

23. The transmitter of claim 22, further comprising a scheduler receiving the TDMA signals and varying said first and second steering control signals to avoid creating adjacent beams having the same polarization during the same timeslot.

24. The transmitter of claim 14, wherein the $2n$ different signals input to successive inputs of each passive coupler pair are split across the passive coupler pairs $2p$ outputs with a phase incremented successively through multiples of an incremental phase.

25. The transmitter of claim 14, further comprising $2n$ power amplifiers receiving the $2n$ different signals and amplifying the $2n$ different signals input to the n beamformers.

26. The transmitter of claim 14, wherein each passive coupler pair input corresponds to transmission by the associated row of p radiating elements connected to the $2p$ outputs of the passive coupler pair with a fan-shaped radiation beam, with different passive coupler pair inputs producing fan beams at different angles relative to said phased array transmitter.

27. A transmitter for simultaneously transmitting *n* different signals in a plurality of directive beams to corresponding destination stations, each destination station located in a separate sub-region within a service area, said transmitter comprising:

n beamformers receiving *n* different signals with each beamformer receiving a signal to be transmitted to an associated sub-region, each of said beamformers having *m* outputs for each different signal to be transmitted;

m passive couplers are operatively connected to said *m* outputs for receiving said *n* different signals to be transmitted simultaneously from said *n* beamformers, each passive coupler having *r* outputs in phased relationship to one another; and

an antenna with an aperture within which a two-dimensional *q* x *p* array of radiating elements are disposed, with a fraction of adjacent radiating elements connected to the *r* outputs of each passive coupler,

wherein *n* is less than or equal to the number of radiating elements coupled by each passive coupler,

wherein each of said *n* beamformers receives steering control signals for steering the direction of each beam within its respective one of said sub-regions.

28. The transmitter of claim 27, further comprising a router receiving the *n* signals, determining which of said sub-regions each of the *n* signals are destined, and routing each of the *n* signals to an appropriate beamformer associated with the respective sub-region, wherein each beamformer, via its steering control signals, steers the direction of each beam to the respective destination station located in the respective sub-region.

29. The transmitter of claim 27, further comprising a single-signal transmit amplifier connected to each of the beamformer outputs.

30. The transmitter of claim 27, wherein the *m* passive couplers comprise *m* Butler matrices.

31. The transmitter of claim 27, wherein the *m* passive couplers comprise *m* two-dimensional Butler matrices.

32. The transmitter of claim 29, wherein the single-signal transmit power amplifiers are operated at saturation.

33. The transmitter of claim 27, wherein said *n* different signals to be transmitted comprise TDMA signals having a number of timeslots within a TDMA frame period, and wherein said steering control signals are varied for each timeslot.

34. A transmitter for simultaneously transmitting a plurality of signals in a plurality of directive beams to corresponding destination stations, each destination station located in a separate fan within a service area, said transmitter comprising:

a plurality of beamformers, each beamformer receiving one of the signals to be transmitted to an associated fan, each of the beamformers having a plurality of outputs for each different signal to be transmitted;

a plurality of Butler matrices each receiving one of the plurality of outputs from the plurality of beamformers for each different signal to be transmitted, each Butler matrix having a plurality of outputs in phased relationship to one another, wherein each of the signals to be transmitted is simultaneously provided across the outputs of each Butler matrix in a phased relationship;

an antenna with an aperture within which a two-dimensional array of antenna elements are disposed, wherein equal fractions of adjacent antenna elements are connected to the outputs of each Butler matrix, wherein each of the plurality of signals are simultaneously transmitted by the entire two-dimensional array of antenna elements,

wherein each of the plurality of beamformers receives steering control signals for steering the direction of each beam within its respective fan.

35. The transmitter of claim 34, further comprising a router receiving the plurality of signals, determining which of said fans to which each of the signals are destined, and routing each of the signals to an appropriate beamformer associated with the respective fan, wherein each beamformer, via its steering control signals, steers the direction of each beam to the respective destination station located in the respective fan.

36. A method for providing simultaneous communication to a plurality of stationary user terminals located at known locations within a plurality of fan beams, said method comprising the steps of:

defining a plurality of fan beams along a first axis, with each of the plurality of fans having a length along a second axis substantially perpendicular to the first axis;

providing a plurality of groups of directional transmitting beams, each of the groups of directional transmitting beams associated with a respective fan beam;

providing a plurality of communication signals each intended for a stationary user terminal;

determining which of the groups of directional transmitting beams to use for transmitting each of the plurality of communication signals to each respective destined preselected fixed user terminal;

multiplexing the plurality of communication signals on respective groups of directional transmitting beams associated with the respective destined stationary user terminal; and

transmitting the plurality of communication signals to each respective destined stationary user terminal via the signal multiplexed directional transmitting beam groups.

37. The method of claim 36, wherein the step of transmitting each group of signal multiplexed directional transmitting beams comprises the step of applying each signal multiplexed beam of the group to a separate Butler matrix.

38. A communications system for providing communication to a plurality of fixed user terminals located at a known locations within a grid of geographical cells, said communications system satellite comprising:

an orbiting satellite in a non-geostationary orbit defining a ground track;

a satellite-borne, multi-beam transmitter simultaneously creating a plurality of directional transmitting beams, each of said transmitting beams having a different angular displacement to the right or left of the satellite's ground track and being electronically steerable in a plane approximately parallel to the satellite's ground track via electronic steering signals; and

a satellite-borne, multi-beam receiver receiving signals from said user terminals including a destination location identifier signal of a terminal for which each signal is destined, said receiver translating the destination location identifier signals to determine which of said directional transmitting beams to use for transmitting each of said signals to its respectively indicated destination terminal.

39. The communications system of claim 38, wherein the receiver generates the electronic steering signals for each of said directional beams based on the destination location identifier signals and a knowledge of momentary satellite position along the satellite's ground track.

40. A scheduler for selecting data packets from a buffer memory to be transmitted in a next time period using multiple directional transmission beams controllable in direction, said scheduler comprising:

a backlog tracker determining a waiting time for each data packet, said waiting time indicative of how long each data packet has waited in the buffer memory for transmission;

a first selector for selecting the data packet that has been waiting the longest as indicated by the backlog tracker; and

a second selector selecting further data packets for simultaneous transmission in descending order of waiting time, said second selector skipping data packets requiring a transmit direction incompatible with the direction of transmission of a data packet previously selected for transmission at a same time.

41. The scheduler of claim 40, wherein a transmit direction is deemed incompatible by the second selector if it can only be created using a directional transmission beam that will be fully occupied in transmitting an already selected data packet.

42. The scheduler of claim 40, wherein a transmit direction is deemed incompatible by the second selector if it lies too close in direction to the direction of transmission of a data packet already selected for transmission at the same time.

43. The scheduler of claim 42, wherein a direction too close in direction to another direction is one in which an angular separation of said directions is less than a minimum value sufficient to avoid mutual interference.

44. The scheduler of claim 43, wherein the minimum angular separation sufficient to avoid mutual interference is a first separation when the polarizations of the transmission used in each direction are the same, and a second separation when the polarizations of transmission used in each direction are different.

45. A scheduling method for selecting data packets from a buffer memory for directive transmission using a number of directive beams, said method including the steps of:

determining a subset of directions in which said directive beams can be transmitted in a next transmission;

mapping a destination identifier code stored with each said data packets to a corresponding beam direction and selecting only data packets whose destinations map to a direction within said subset of directions;

ordering said selected data packets according to how long they have been stored in said buffer memory, with said selected data packets which have been stored the longest ordered first; and

transmitting the selected data packets that have been stored the longest first.

46. The scheduling method of claim 45, further including the step of deleting the selected data packets from the buffer memory which have been transmitted.

47. The scheduling method of claim 45, further including the step of setting an indication flag in the buffer memory in association with the selected data packets already transmitted.

48. The scheduling method of claim 45, further comprising the step of releasing memory locations in the buffer memory where the selected data packets that have been transmitted were stored so as to provide storage capacity for new data packets.

49. A method of preventing fraudulent or unauthorized use of a communications satellite, said method comprising the steps of:

providing a logon procedure in which a user terminal desirous of service communicates with a network computer using an authentication procedure based on shared secret data to establish a session key;

storing the session keys for logged-on user terminals in the satellite;

using the session keys in said user terminals to provide transmission from the user terminals to the satellite with a verifiable signature;

checking the signature of signals received at the satellite using the stored session keys to verify the identity of the source; and

transmitting signals received at the satellite to their indicated destinations only if the identity of the source is verified to be an authentic user terminal.

50. The method of claim 49, wherein the step of checking the signature of signals received at the satellite comprises the step of enciphering a cyclic redundancy check code using the stored session keys, wherein the cyclic redundancy check code is a function of all data bits defined by the signal received at the satellite.

51. The method of claim 49, wherein the step of checking the signature of signals received at the satellite comprises the step of enciphering data packet headers containing addressee/addressor identifiers, packet numbers and error check codes as a function of the stored session keys.

52. The method of claim 51, wherein the data packet header and payload are enciphered using the stored session keys before being error correction coded for transmission.

53. The method of claim 52, wherein the step of enciphering data packet headers, containing addressee/addressor identifiers, packet numbers and error check codes as a function the stored session keys is accomplished utilizing a block cipher.